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ORIGINAL ARTICLE

Anterior cruciate ligament reconstruction: Hamstring Tendon autograft versus Bone Patellar Tendon Bone autograft: what about muscular and functional capacities?

EXERCISE IS MEDICINE

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Abstract

Purpose: Comparison of surgical techniques by evaluating functional capacities: power, strength, velocity and dynamic stability of knee extensor and flexor muscles after ACL reconstruction. Material and Methods: a prospective study with a retrospective comparative cohort of 111 patients (mean age 30 years (14.4 – 49.7). *Outcomes:* 18 outcomes were considered. Objective outcomes were the difference of power, strength, velocity and dynamic stability. Subjective outcomes included Tegner activity scale, Lysholm score, KOS, KOS-SAS (Knee Outcome Survey-Sport Activities Score), Tampa scale-Q. Results: The BPTB group performed better in 14 of 18 observed outcomes. 6 were statistically significant (velocity in quadriceps and hamstring, hamstring power-max, mean-power, Tegner score and KOS-SAS). No statistical difference in the stability capacities was shown between the both groups. The results were adjusted for age, gender, body-mass-index and follow-up time.

Conclusions: The use of a BPTB autograft achieved better muscular and functional capacities than the HT autograft.
Level of evidence III

Resumé

Objectif: Comparaison de technique chirurgicale (Bone-patellar-tendon-Bone (BPTB) / HT (hamstring tendon) lors de l'évaluation de capacités fonctionnelles: puissance, force, vitesse et stabilité dynamique des

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muscles extenseurs et
fléchisseurs après reconstruction du LCA (Ligament croisé antérieur). Méthode: une étude prospective avec une cohorte comparative rétrospective de 111 patients (moyenne d'âge 30 ans (14.4 – 49.7). Outcomes: 18 indicateurs ont été évalués. Les indicateurs objectifs étaient la différence de puissance, force, vitesse et stabilité dynamique. Les indicateurs subjectifs incluaient le score de Tegner, Lysholm, KOS, KOS-SAS (Knee Outcome Survey-Sport Activities Score), Tampa scale-Q. Résultats: Le groupe BPTB avait de meilleures performances dans 14 des 18 indicateurs observés. 6 étaient statistiquement significatifs (vitesse du quadriceps et ischio-jambiers, puissance max. des ischiojambiers, puissance moyenne, score Tegner et KOS-SAS). Aucune différence statistique pour les capacités de stabilité entre les deux groupes. Les résultats ont été ajustés pour l'âge, le genre, l'index de masse corporelle et le temps du suivi.

Conclusion: Dans cet échantillon, l'utilisation du greffon BPTB permet de meilleures capacités musculaires et fonctionnelles que le greffon IJ. Degré d'évidence III

Introduction

The most commonly used autografts for anterior cruciate ligament (ACL) reconstructions are the bone-patellar tendon-bone (BPTB) autograft and the hamstring tendon (HT) autograft [1,2]. Previous studies [1,5], regarding this surgery have often compared and evaluated muscular capacities of the 2 techniques using isokinetic measurements and not functional capacities. Few studies describe how important it is to restore normal muscle strength, balance, proprioception and other neuromuscular indices required for high-risk activities involving cutting, twisting, turning, jumping and pivoting [8,9]. Nevertheless some muscles strength deficits in the operated leg remain over years and perturb the kinematics of the operated knee [6]. This deficiency may lead to functional instability which impair an athlete to perform sports [7]. For example, hamstring muscles contribute to stabilisation in the ACL-injured knee [8]. Some studies show that the graft choice can have an influence on strength deficits [1], kinesiophobia [9], stability and jumping capacities [10] after surgery. However many ACL-reconstructed patients return to their previous level of activity[11]. Based on findings and previous studies that discussed additional important parameters a more extensive battery of tests to assess functional performance was suggested [10]. In the light of our practical experience, we wanted to evaluate these functional capacities. To achieve this, it is important to perform clinical tests [11]. Isolated knee concentric muscular testing, single-leg hop test, subjective knee scores must be measured to determine the functional muscular properties between the operated and non-operated leg and between the 2 grafts [12].
The purpose of this study was to assess functional and muscular properties using subjective and objective outcomes in operated and non-operated side of two ACL surgical techniques. We hypothesize a) there is persisting strength deficit for hamstring muscle between operated and non-operated leg over two to five years, b) the quadriceps strength deficit persist only two years and diminish afterwards c) the balance capacities is better in the operated leg, d) for the BPTB graft the fear of jumping persist over the years but not the kinesiophobia, e) all observed parameters are associated with kinesiophobia, f) the velocity by both graft is diminished, g) all patients return to an physical activity.

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Materials and Methods

Study design: prospective study in a retrospectively identified cohort. *Inclusion's criteria* were patients with an ACL tear operated by the same surgeon at "Hôpital du Valais", without any previous ligamentous injury and/or surgery of either knee, no previous meniscal pathology treated with resection or repair. *Exclusion's criteria* were controlateral ACL reconstruction, previous ipsilateral surgery, previous controlateral surgery, graft failure, non- traceable patients, relevant musculoskeletal impairment and patients > 50 years old. Details of the recruitment process, full inclusion and exclusion criteria are in figure 1.

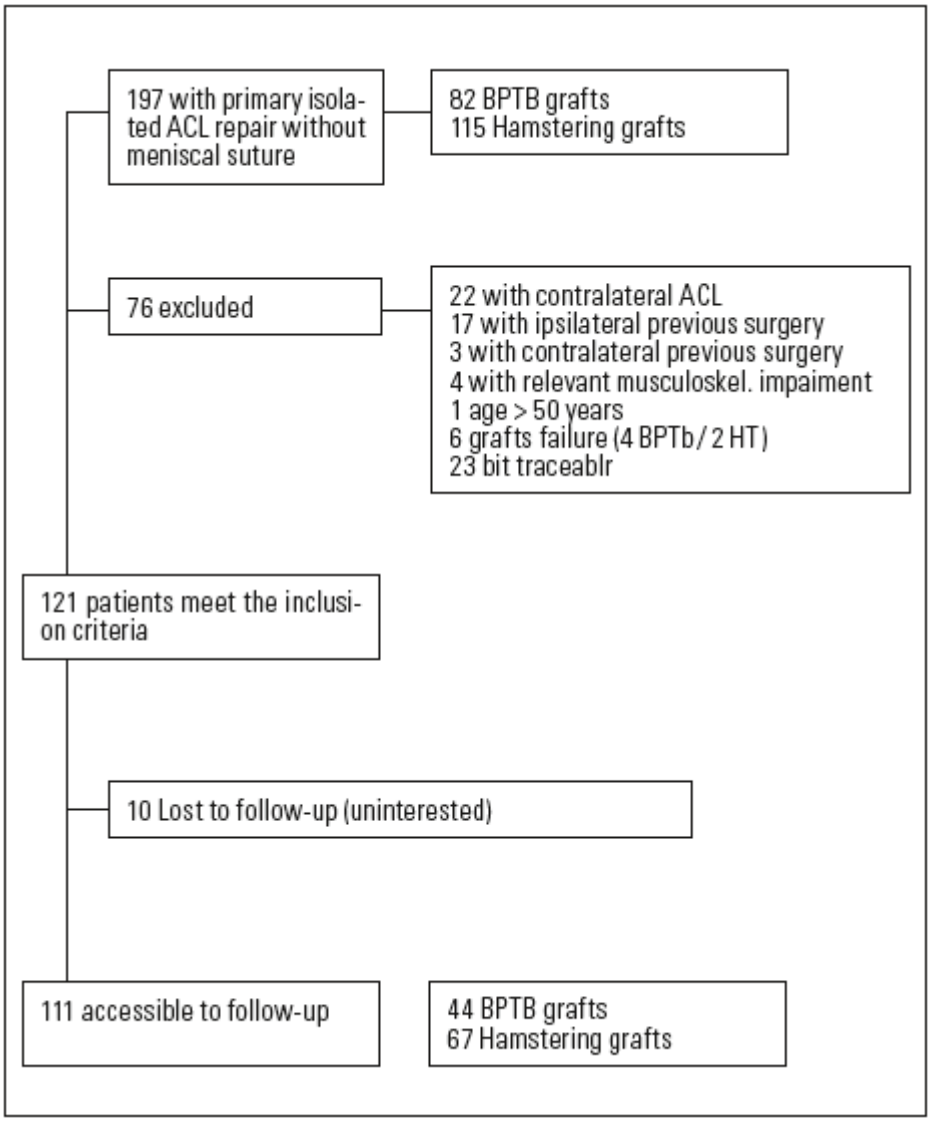

Figure 1: Flow of the participants through each stage of the study.

Participants

Of 197 operated patients, 121 met the inclusion criteria. Finally, we enrolled 111 patients (92%) (47 females – 64 men), aged 30 years (range 14.4–49.7). The interval between accident and surgery was 7.3 months (21

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days – 117 months). 44 patients had received a BPTB (16 women – 28 men) and 67 an HT (31 women – 36 men) *(Table 1).* The study was conducted following the approval by the institutional ethical committee on Human Research (Commission cantonale Valaisanne d'éthique médicale no CCVEM 036/12). All subjects gave their written informed consent.

	Grafts		p-value of difference (t-test)	Effect size Index
	HT	BPTB		
Age	32.8 (10.4)	25.9 (7.5)	<0.001	0.74
Gender (% men)	54	64		
Follow-up duration (months)	39.6 (11.59)	54.1 (11.05)	<0.001	1.27
BMI (at follow-up)	23.4 (3.2)	24.2 (3.8)	NS	0.23

Table 1: Patient characteristics

BMI: Body Mass Index, HT: Hamstrings Group, BPTB: Bone-Patellar-Tendon-Bone

Data assessment

All measurements were carried out on average 45.4 months (range 23.0–71.1 months) postoperatively by the same two senior physical therapists, not blinded to the type of surgery. Before testing, the subjects performed a 10-min warm-up on a stationary bicycle (Intensity of Borg scale around 12/20). Subjects were also asked to complete 5 questionnaires (Tegner, Lysholm, KOS, KOS-SAS, Tampa-Q). Equipment, data collection and the warm-up procedure were standardized.
Quadriceps and hamstring muscle capacities of operated and non-operated limb were assessed with maximal isotonic contraction. Quadriceps (knee extension) and Hamstring (knee flexion) isotonic strength were assessed with a Myotest®; a valid accelerometer measure instrument (Sion-Valais-Switzerland). Power was expressed in maximal peak torque in W/Kg, strength in Nm/Kg, velocity in m/sec. 3 trials of 5 repetitions were recorded and averaged. Before data collection was started, the subjects had performed one practice repetition. After a-min rest, 5 maximal extension concentric efforts were performed. The same procedure was applied for the flexion. The testing protocol of each functional test included 3 practice trials on each limb. Subjects were encouraged to make a maximal effort. They were allowed to recover 30 seconds between the trials. The left leg was tested first and then the same procedure was performed to the right. The tested leg was fixed on the bench. During testing, the subjects were allowed to grasp the bench with their hands. For the quadriceps test, the subject was in sitting position and performed an extension from 90° knee flexion to 0° extension. In the hamstring-test, the subject was in the ventral position and performed a knee flexion from 0° to 90°. The pelvis was fixed. Regarding the moved load, we respected the ratio agonist – antagonist for quadriceps and hamstrings [13].
The dynamic knee stability was evaluated with 2 functional tests. The single-leg hop test measures the plyometric capacities. It was conducted using the protocol described by Bosco [14], the measuring instrument was the Myotest®. This test begins on 1 leg; left leg first. It was performed hopping upward as high as possible, hands at the pelvis and landing on both legs. 3 trials of 5 jumps were recorded and

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averaged. Then the same procedure was repeated with the right lower limb. The second dynamic stability testing was performed with "the Olympic-test" validated by Myotest®, a modified Bass-Test of dynamic balance [15]. For this test, the subject performed 6 hops upwards and forwards alternately from the left to the right leg; left leg first. The goal was to jump as high as possible and to stabilize the lower limb as quickly as possible. The next jump was signalled by a tone (bip). The height and the stabilisation time averages of each leg (3 jumps) were measured.
Before completing the functional testing protocol, self-reported knee function was assessed using the Tegner scale [16], the Lysholm score [16], the KOSS (Knee Outcome Survey Sports), the KOS-SAS (Knee Outcome Survey Sports Activities Scale) [17], and the Tampa-scale Q [6,16].

Statistical analysis

Statistical analysis was conducted with the SPSS (Version 20.0, SPSS Inc., USA). The t-test for equality of means was used for comparison of differences between groups. Differences were considered statistically significant when $P<0.05$. Analysis of variance, adjusting for gender, age, body-mass-index and follow-up was used for the between-group comparisons. The effect size index (ESI) for the t-test of the difference between independent means is expressed in units of the within-population standard deviation (0.2 = small effect; 0.5 = moderate effect; 0.8 = large effect) [18].

Results

Objective Outcomes

Isotonic test: Statistical significant difference in favour of the BPTB group for quadriceps velocity, HT mean-power, HT power-max, HT velocity *(table 2).* Single-Hop-test. No statistically significant (NS) difference was observed between groups *(table 3)*. Dynamic Knee Stability. No statistically significant (NS) difference was observed between groups *(table 4)*.

Subjective Outcomes

Self reported Questionnaire. Statistically significant results for the Tegner score and KOS-SAS scores were observed in the BPTB group *(table 5)*.

	HT	BPTB	Graft-difference	Sign. (P)	Effect size Index
	Mean diff op vs non-op (SD)	Mean diff op vs non-op (SD)			
4-ceps mean power	-0.65 (1.93)	-0.14 (1.51)	-0.51 (-1.2 to 0.17)	NS	0.3
4-ceps power max	-0.82 (2.28)	0.78 (13.90)	-1.6 (-5.02 to 182)	NS	0.2
4-ceps strength	0.19 (2.23)	0.19 (1.59)	0.004 (-0.76 to 0.77)	NS	0
4-ceps velocity	-3.2 (10.26)	0.918 (9.37)	-4.15 (-7.98 to -0.34)	0.03*	0.4
HT mean power	-2.00(6.02)	0.05 (1.30)	-2.05 (-3.9 to -0.20)	0.03*	0.5
HT power max	-1.54(2.57)	-0.01(1.66)	-1.52 (-2.34 to -0.71)	0.00*	0.7
HT strength	-0.17 (2.58)	2.36 (11.59)	-2.53 (-6.15 to 1.09)	NS	0.3
HT velocity	-12 (38.3)	0.67(6.60)	-12.62 (-24.36 to -0.89)	0.03*	0.5

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Table 2: Results of all measures (* statistically significant)

	HT	BPTB	Graft-difference	Sign. (P)	Effect size Index
	Mean diff op vs non-op (SD)	Mean diffop vs non-op (SD)			
Bosco power	-0.02 (5.92)	-1.07(1.30)	1.05 (-0.77 to 2.9)	NS	0.3
Bosco strength	-1.5 (7.26)	-0.26(1.47)	-1.24 (-3.47 to 0.1)	NS	0.3
Bosco velocity	-6.05 (14.18)	-1.9 (12.79)	-4.16 (-9.46 to 1.14)	NS	0.3

Table 3: Results of single-hop test (Bosco)

	HT	BPTB	Graft-difference	Sign. (P)	Effect size Index
	Mean diff op vs non-op (SD)	Mean diff op vs non-op (SD)			
Dyn. Stabil. Height	-0.19 (1.88)	-0.13 (2)	-0. 06 (-0.8 to 0.68)	NS	0.02
Dyn. Stabil. Time	0.04 (0.8)	-0.06 (0.7)	0.11 (-0.18 to 0.4)	NS	0.15

Table 4: Results of "Olympic-test"

	HT	BPTB	Graft-difference	Sign. (P)	Effect size Index
Tegner score	6.28 (1.45)	6.91 (1.46)	-0.62 (-1.2 to -0.6)	0.03*	0.4
Lysholm score	91.91 (7.62)	91.73 (6.66)	0.18 (-2.6 to 2.9)	NS	0
Tampa scale Q	33.43 (6.52)	33.45 (6.14)	-0.2 (-2.4 to 2.4)	NS	0
KOS	48.78 (5.03)	49.45 (4.08)	0.68 (-2.4 to 1.1)	NS	0
KOS-SAS	88.48 (11.78)	92.16 (7.71)	-3.7 (-7.35 to -0.01)	0.04*	0.37

Table 5: self reported questionnaire (*statistically significant)

Discussion

The main findings of our study comparing graft techniques is that the BPTB group performs better in 14 of the 18 observed outcomes. There are 6 statistically significant differences in favour of this group: velocity in quadriceps and hamstring, hamstring power-max and mean-power, Tegner score and KOS-SAS.
In the Bosco test (single-hop test), there is a trend of better results (NS) regarding the power in the HT

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group. The hypothesis is that the BPTB group develops weakness and loss of power in the transition between eccentric and concentric muscle contraction. The same is true for the “Olympic test” (Bass test modified by Riemann), where the HT group tends to be better for the stabilization time (NS). The hypothesis is that during landing, a weakness appears in the eccentric potential of the quadriceps muscle. Our results are in agreement with others studies [7,19] which show that BPTB grafts answer the demands of strength and power better than HT grafts. Dauty et al. [20] found that the BPTB group showed a greater peak flexion torque in the isokinetic strength test of the hamstring muscles but their follow-up was shorter. This phenomenon has been previously described in the literature as a hamstring overachievement [1,9]. It may be due to the diminished quadriceps strength, possibly related to the new neuromuscular situation in the ACL-reconstructed knee and the relative increased demand of the hamstrings to aid in the stabilization of the knee joint [2]. Some studies don’t find significant differences between the two grafts but they have evaluated among others the anterior knee laxity, rotational knee joint stability and the isokinetic muscle peak torque [12].

The strengths of our study are the sample size, the functional outcomes observed and the length of the follow-up (mean: 45.4 months). Therefore all the patients were operated by the same surgeon in the same hospital and with the same procedure for both types of grafts. After 2 years the operated leg often recovers an optimal level of muscle capacities [21].

The study suffers some limitations; mainly that the retrospective cohort was not randomized with regard to the surgical interventions. We cannot exclude that confounding factors were not detected due to non-measured variables. However, we adjusted for age, gender, body-mass-index and follow-up time. This would have allowed a better adjustment of the statistical analyses. Another limit concerns the power testing of hamstring muscle; we stopped the movement at 90° flexion. The deficits may be greater if the movement was allowed till the end of range of motion. In most sports knee flexion above 90° is seldom used. We didn’t measure the Tegner score before the ACL reconstruction, we only registered this after the rehabilitation to compare both group. It was not our intention to compare pre and post-operative physical activity level. Albeit the mentioned limitations, our study has clinical relevance and gives stronger arguments to the surgeon for the graft choice.

We are aware that rehabilitation following ACL reconstruction should consider not only muscular and functional capacities (strength, power and velocity of muscle). We should also control postoperative pain and swelling, protection of the healing graft, restoration of a full range of motion symmetric to the controlateral knee, stabilization of the knee, hip, and trunk. Neuromuscular control and a gradual progression to functional activities are required for a safe return to sports [22] and prevention of re-injury [21,23].

Conclusion

The use of a BPTB autograft in our study achieves better knee extensor and flexor velocity and power than the HT autograft. Our clinically relevant study gives stronger arguments to the surgeon regarding the graft choice. Surgery together with complete criterion-based (objective and subjective) rehabilitation and sport-specific exercises should improve functional stability of the operated knee. In addition, adequate functional muscle capacities (power, strength, velocity) should be used as a critical criterion for a safe return to a pre-injury level of physical activities. A prospective study should be conducted to validate the present results.

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Conflict of interest

The authors confirm that they have no conflicts of interest.

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ACL DYNAMIC STABILITY FUNCTIONAL CAPACITY MUSCLE-POWER